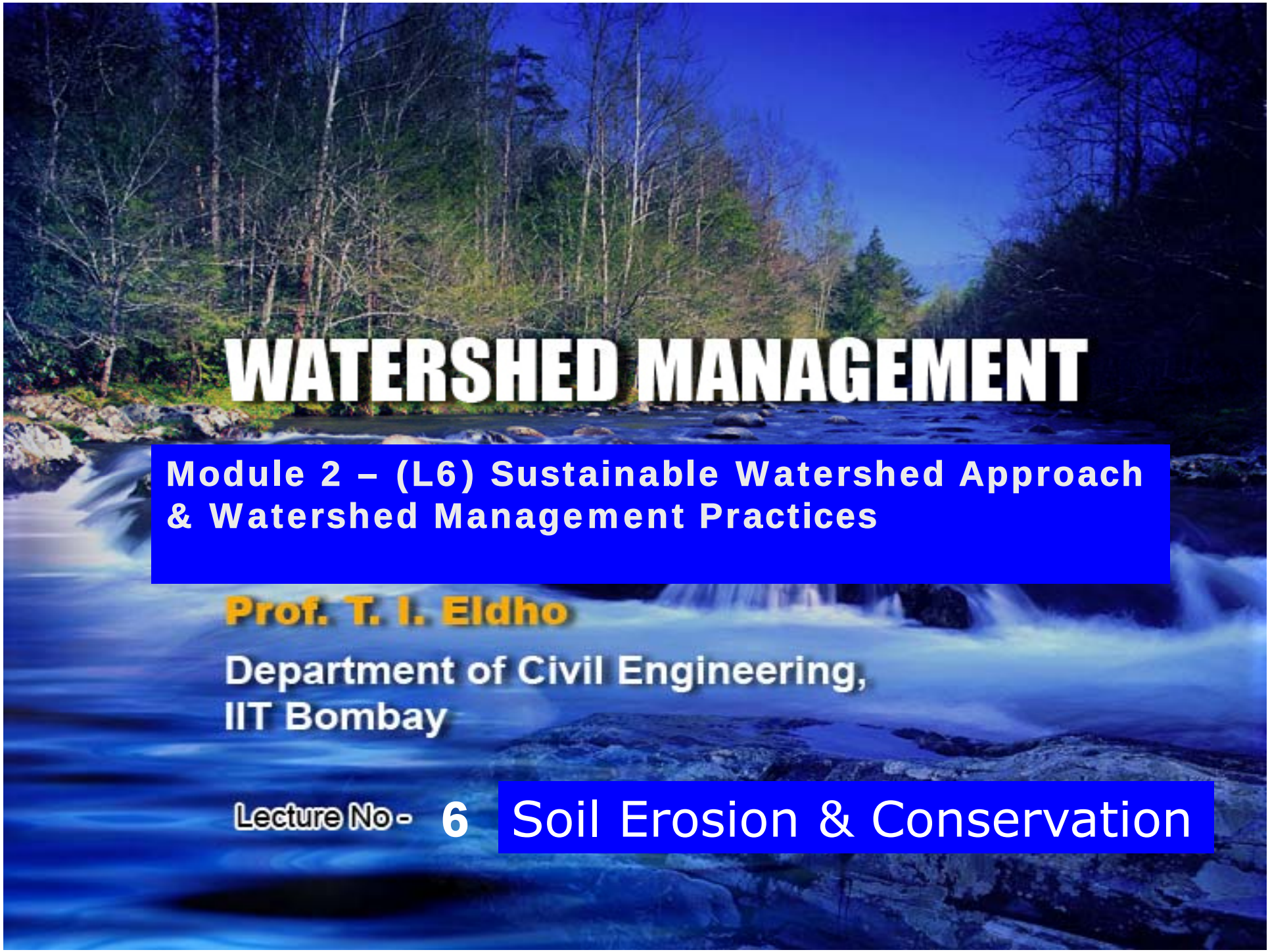
WATERSHED MANAGEMENT
Module 2 – (L6) Sustainable Watershed Approach & Watershed Management Practices
Prof. T. I. Eldho
Department of Civil Engineering,
IIT Bombay
Lecture No - 6
Soil Erosion & Conservation

L6– Soil Erosion & Conservation

- **Topics Covered**
- Soil erosion: causes, processes, erosion factors, water erosion, types, estimation of soil loss, wind erosion, soil conservation practices
- Keywords: Soil erosion, Water erosion, Wind erosion, Soil conservation.

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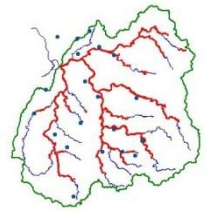


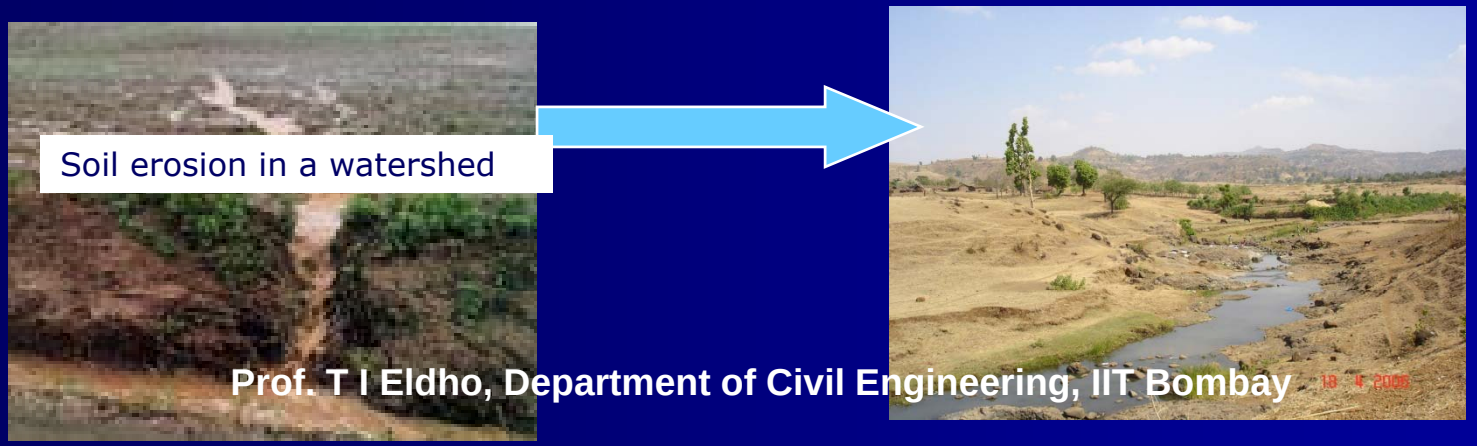
Introduction to Soil Erosion

- Definition :
  - soil erosion is the detachment, transport & deposition of soil particle on land surface - termed as loss of soil.
  - measured as mass /unit area - tonne/ha or Kg/sq.m
- Soil loss is of interest primarily on-site effect of erosion such as loss of crop productivity
- Off site effect of erosion are siltation in ditches, streams , reservoirs
- Sediment generated by erosion processes are prime carrier of agricultural chemicals that pollutes stream or lakes.

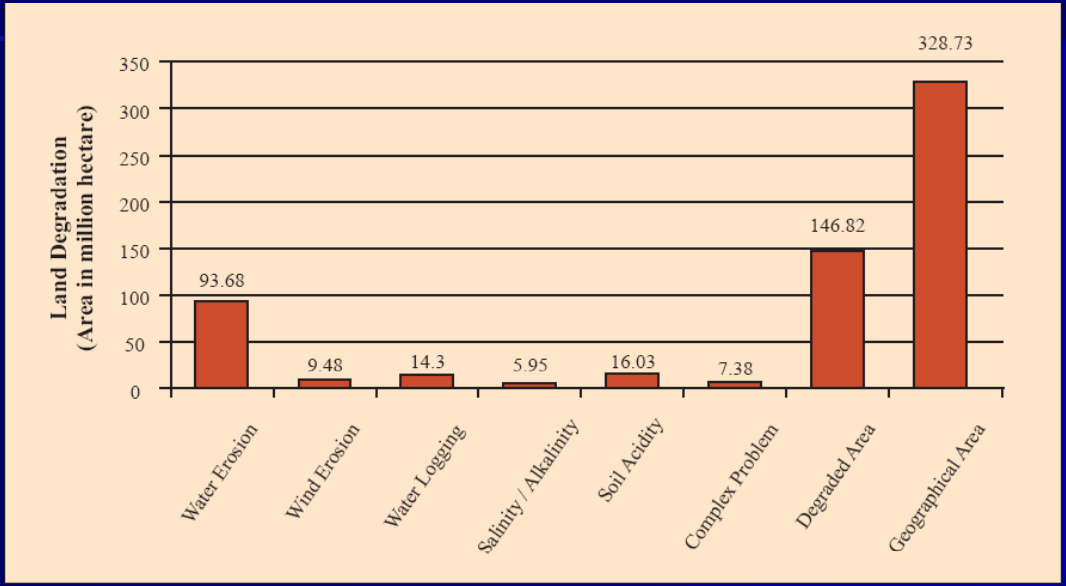
Soil Erosion problem

Soil Erosion Problem

- Soil is the most precious gift of nature -Prime resource-for food, fodder etc. -Soil mismanaged-less productivity.
- In India, more than 100 million hectares →soil degraded, eroded, unproductive
- About 17 tones/ha soil detached annually->20% of this is transported by river to sea→10% deposited in reservoir results 1 to 2% loss off storage capacity.



Soil Erosion Problem…



India's Land Degradation: Source: state of environment report 2009 MoEF

- Soil erosion deteriorates soil quality & reduces productivity of natural , agricultural & forest ecosystem
- Soil erosion deteriorates quality of water
- Increased sedimentation causes reduction of carrying capacity of water bodies.

Causes of Soil Erosion

- **Human Induced & Natural Causes**
- Land use - Over grazing by cattle, Deforestation, arable land use, faulty farming, construction, mining etc.
- Climatic conditions: precipitation & wind velocity
- Soil: soil characteristics - texture, structure, water retention and transmission properties.
- Hydrology: Infiltration, surface detention, overland flow velocity, and subsurface water flow.
- Land forms: Slope gradient, slope length and shape of slope

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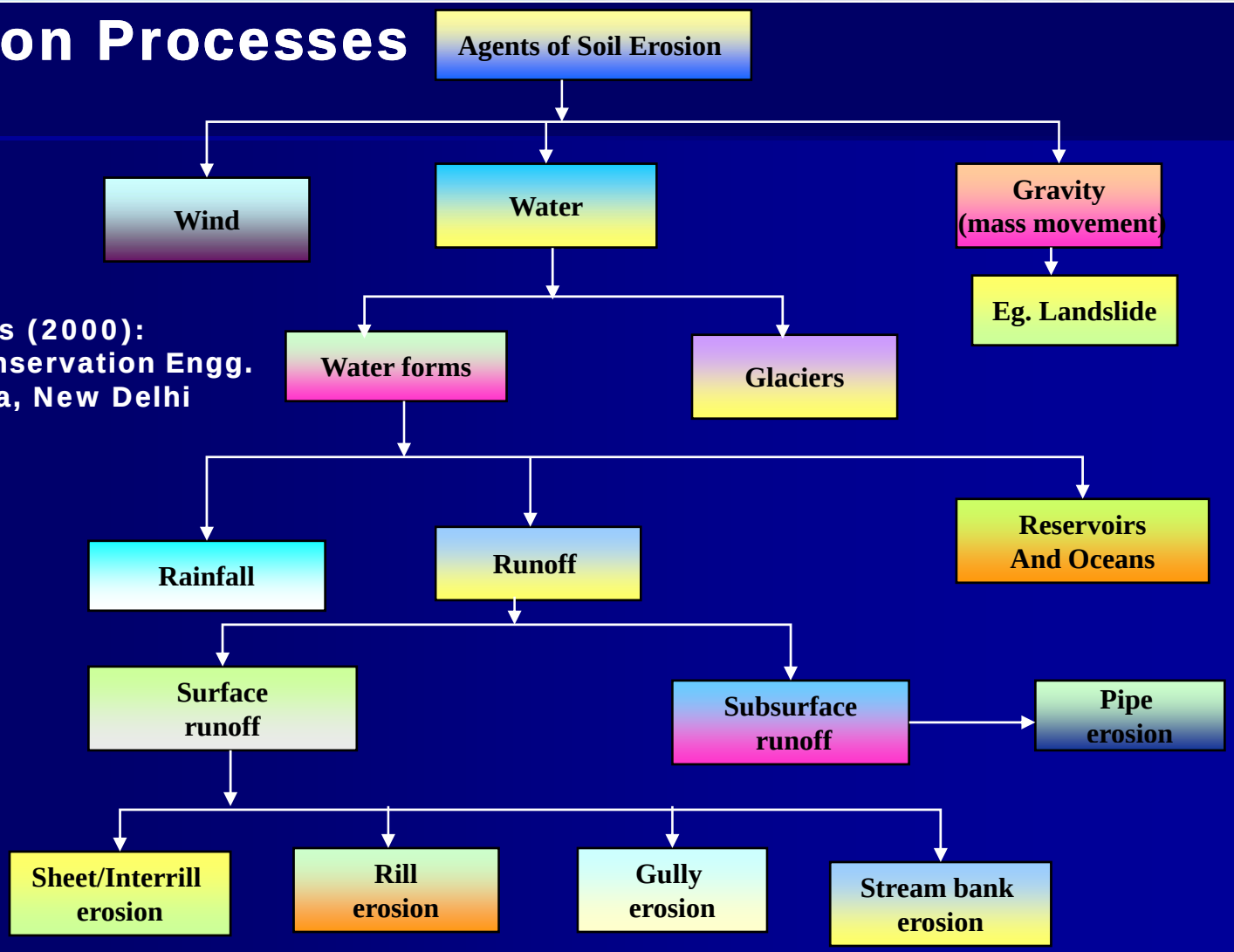
Soil erosion in a watershed

Types of Soil Erosion

- Geological erosion, Natural erosion & Erosion from activities of human & animals
  - Geological erosion:-Soil forming and distribution →Long time process
  - Human and animal:-Tillage, removal of plants and other vegetation →accelerated erosion
  - Stream bank erosion
  - Landslide, Volcanic eruption, flooding
  - Water and wind: major factors of soil erosion

Soil erosion in a watershed

Soil Erosion Processes



Based on Ref: G. Das (2000): Hydrology & Soil Conservation Engg. Prentice Hall of India, New Delhi

Soil Erosion Parameters

- Soil erosion – function of:
  - Erosivity – depends on rainfall
  - Erodibility – property of soil
  - Topography – property of land
  - Management – contributed by man

  Erodibility: Detachability & transportability

  Topography: Slope, length, relation to other land

  Management: Land use & crop management

Water Erosion

- Detachment & transport of soil particles from land mass by water including rain, runoff, melted snow
- Depends on: soil nature & capacity of water to transport
- More on sloppy land
- More velocity→ more transport
- Water erosion → accelerated by agriculture, grazing and construction activities


Soil erosion in a watershed

Factors affecting Erosion by water

- Climate →Precipitation, temperature, wind, humidity and solar radiation
- Soil →size, type of soil, soil texture, structure, organic matter
- Vegetation →interception of rainfall-reduce surface sealing & runoff, decrease surface velocity, improvement of aggregation, increased biological activity and aeration, transpiration, physical holding
- Topography→ degree of slope, shape and length of slope and size and shape of watershed

Types of Water Erosion

- **Water Erosion Types:** Interrill (raindrop and sheet), rill, gully & stream channel erosion
- **Raindrop erosion** (splash erosion) →Soil detachment & transport - from impact of raindrops directly on soil particles or on thin water surfaces
- On bare soil → about 200 t/ha soil is splashed into the air by heavy rains
- Relationship - erosion, rainfall momentum & energy - by raindrop mass, size, shape, velocity & direction
- Relationship: Rainfall intensity & energy (Foster et al., 1981)
- $E = 0.119 + 0.0873 \log_{10} i$; E- kinetic energy in MJ/ha-mm; i = intensity of rainfall in mm/h

Sheet Erosion / Interrill Erosion

- **Sheet erosion:** Uniform removal of soil in thin layers from sloping land resulting from overland flow - Idealized form of sheet erosion rarely occurs
- Splash & sheet erosion sometimes combined & known as Interrill erosion
- Function of soil properties, rainfall and land slope

Watson and Laften(1986) formula

$$D_i = K_i i^2 S_f$$

where, D_i- interrill erosion rate in kg/m^2-s

K_i-interrill erodibility of soil in kg-s/m^4 and i-rainfall intensity in m/s

S_f-slope factor=1.05 - 0.85exp(-4sinθ); θ-slope in degrees

Rill erosion

- Detachment and transport of soil particles by concentrated flow of water; Predominant form of erosion; Depends on hydraulic shear of water flowing in the rill, rill erodibility and critical shear
  - Critical shear: shear below which soil detachment is negligible
  - Rill detachment rate (Dr)-erosion rate occurring beneath submerged area of the rill

$$D_r = K_\tau (\tau - \tau_c)\left(1 - \frac{Q_s}{T_c}\right)$$

Dr-Rill detachment rate in kg/m2-s
Kτ-Rill erodibility resulting from shear in s/m
τ_c-critical shear below which no erosion occurs in Pa
Qs-rate of sediment flow in kg/m-s
Tc-sediment transport capacity of rill in kg/m-s
τ-hydraulic shear of flowing water in Pa=ρ g r s
where, ρ-Density of water in kg/m3; g-acceleration due to gravity in m/s2
r-hydraulic radius of rill in m; s-hydraulic gradient of rill flow


Soil erosion in a watershed

Gully erosion

Advanced form of rill erosion –forms larger channels than rills

- **Four stages**
  - Formation stage
  - Development stage
  - Healing stage
  - Stabilization stage
    - Gullies may be small-1m or less
    - Medium-1m to 5m
    - Large-more than 5m
- **Stream channel Erosion:** Removal of soil for stream banks or soil movement in channel


Gully & rill erosion in a watershed


Soil erosion in a watershed

Measurement of Soil Loss – Water Erosion

- Measurement from runoff plots
  - Size varies from 1/250 to 1/125 Hectare
  - Runoff measured by Flume
- Measurement from streams
  - Silt observation Posts (SOP)
  - Suspension, saltation and surface creep (bed load)
  - Both separately measured and added
  - Soil Sampler: $S = p^* q^*86400/1000$
- S-amount of material transported in tones/day
- p-amount of material ($1m^3$ of water in kg),
- q-rate of stream flow in m^3/sec

Estimation of Soil Loss- Water Erosion

- Universal soil loss equation (USLE) (through experiments) (Raj Vir Singh, 2000)

$$A = RK\ L\ S\ C\ P$$

  - A-Average annual loss: in ton/ha/year
  - R-Rainfall & runoff erosivity index for location
  - K-Soil erodibility factor
  - L-slope length factor
  - S – slope steepness factor
  - C-cover management factor
  - P-conservation practice factor

Rainfall and Runoff Erosivity Index (EI)

$$EI_{30} = \left(KE\ I_{30}\right)/100$$

- EI-by multiplying kinetic energy of storm to maximum 30 min. intensity for that storm
- KE-kinetic energy of storm
- I_{30}=Maximum 30 minutes rainfall intensity of storm
- KE=210.3 + 89 log I - in ton/ha-cm
- I-rainfall intensity in cm/hr

Erodibility factor (K)

- Soil erodibility factor K can be found by regression equation by Foster et.al(1981)

$$K = 2.8*10^{-7} M^{1.14}(12-a) + 4.3*10^{-3}(b-2) + 3.3*10^{-3}(c-3)$$

Where, M-particle size parameter (% silt+% very fine sand)*(100-%clay)

a-percent organic matter; b-soil structure code

(very fine granular 1, fine granular 2, Medium or course granular 3, blocks, platy or massive 4)

c-profile permeability class (rapid 1;moderate to rapid 2;moderate 3;slow to moderate 4;slow 5;very slow 6)

Slope Length Factor (L)

$$L = \left(\frac{I}{22} \right)^{m}$$

Where, L-slope length factor; I-slope length in m

m- dimensionless exponent

$$m = \frac{Sin\theta}{Sin\theta + 0.269(Sin\theta)^{0.8} + 0.05}$$

Where θ-field slope steepness=$\tan^{-1}(s/100)$

- s-field slope in %

Slope Steepness Factor (S)

- Slope Length shorter than 4m

$$S = 3.0(\sin\theta)^{0.8} + 0.56$$

- For slope length longer than 4m and s<9%

$$S = 10.8\sin\theta + 0.03$$

- Slope length more than 4m and s >= 9%

$$S = 16.8\sin\theta - 0.5$$

Crop management factor (C)

- Combined effect of crop sequences, productivity level, length of growing season, tillage practices, residue management & expected time distribution of erosive rain storm with respect to planting & harvest date

	Crop	Soil loss (tn/ha)	Value of C
Eg. Hyderabad	Cultivated	5	1
	Grass	0.59	0.12
	Bajra	2	0.38

Conservation practice factor (P)

- Ratio of soil loss with a specific supporting practice to the corresponding loss with up & down cultivation

e.g.	Practice	P factor
Kanpur	a) Up and down cultivation of Jowar	1.0
	b) Contour cultivation of Jowar	0.39

Wind Erosion

- Process of detachment transportation and deposition of soil by action of wind
- Depends on wind speed, soil, topographic features and vegetative cover
- More problems in arid or semi-arid region
- Change in texture of soil
- In India: Mainly occur in Rajasthan, Gujarat and parts of Punjab

Wind erosion in a watershed

Mechanism of Wind Erosion

- Initiation of movement –due to turbulence and wind velocity
- Transportation –depends on particle size, gradation, wind velocity and distance
- Deposition—occurs when gravitational force is greater than forces holding soil particles in air
- Types of soil movement by wind
  - Saltation- Fine particles lifted from surface and following specific path w.r.t wind and gravity
  - Suspension-floating of small particles
  - Surface creep -rolling or sliding of large soil particles along soil surface.

Estimation of Wind Erosion

- Average annual loss

$$E = f(I, K, C, L, V)$$

- Where, E-estimated average annual loss (tn/ha/year)

I- soil erodibility index (ton/ha-yr), K-ridge roughness factor, C-climate factor, L-unsheltered length of eroding field (m), V-vegetative cover factor

I-Soil erodibility index (ton/ha-yr)

$$I = 525\,(2.718)^{-0.05\,F}$$

F-% of dry soil fraction greater than 0.84 mm

Roughness Factor

- A measure of effect of ridges made by tillage implements on wind erosion
- Ridge roughness in mm

$$K_r = \frac{0.16h^2}{d}$$

h-ridge height in mm; d-ridge spacing in mm

from K_r, roughness factor K

$$K = 0.35 + \frac{12}{(K_r + 18)} + 6.2 * 10^{-6} Kr^2$$

Climatic Factor

- Index of climatic erosivity-> depends on wind velocity and soil surface moisture

Mean wind velocity profile expression

$$u_z = \frac{u^*}{\kappa} \ln\left(\frac{z-d}{z_o}\right)$$

Where, u_z-wind velocity at z height (L/T)

u^*-friction velocity (L/T)= $(\tau 0/\rho)^{0.5}$
τ_0-shear stress at boundary (F/L^2)
ρ-air density (m/L^3)
k- Karman's constant=0.4
z-Height above a reference surface
d-an effective surface roughness height
z_0-a roughness parameter (h)
d=0.7h; z_0=0.13h
h-height of vegetation

Unsheltered Belt & Vegetative Cover Factor

- Unsheltered distance (L)- Distance from a sheltered edge of a field to end of unsheltered field
- Vegetative Cover- Factor represented by relating the land, quantity and orientation of vegetative material to its equivalent of small grain residue

$$V = aR_w b$$

- V-vegetative cover factor expressed as small grass equivalent in kg/ha; a, b-crop constants
- R_w – quantity of residual to be converted to small grain equivalent in kg/ha

Photo, A.K. Singh, 2002

Preventing Soil Erosion

- **Preventing soil erosion requires political, economic & technical changes.**
- Aspects of technical changes include:
- use of contour ploughing and wind breaks;
- leaving unploughed grass strips between ploughed land;
- making sure that there are always plants growing on the soil, and that the soil is rich in humus (decaying plant and animal remains).
- avoiding overgrazing and the over-use of crop lands;
- allowing indigenous plants to grow along the river banks
- encouraging biological diversity by planting several different types of plants together;
- conservation of wetlands.

Soil Conservation Practices

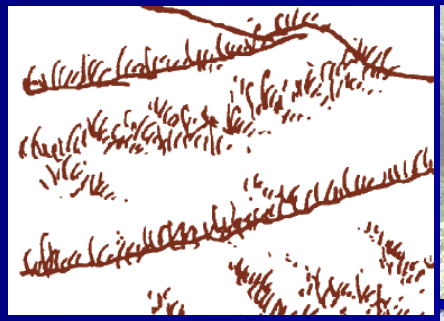
- **Conservation measures** - reduce soil erosion by both water & wind.
- **Tillage and cropping practices**, as well a land management practices, directly affect the overall soil erosion problem.
- **Combination of approaches** (Eg. contour plowing, strip cropping, or terracing)
- **Other measures:** Silt Fencing, Erosion Control Blankets, Sediment Traps, Plastic Covering/Bank Stabilization, Pipeline Sand Bagging, Check Dams, Drain Inlets, Filter Berms & Silt Dikes

Photo, A.K. Singh, 2002

Photo, A.K. Singh, 2002

Soil Conservation Practices - Types

- Vegetative practices
  - Contouring
  - Strip cropping
  - Tillage operations
  - Mulching
- Mechanical practices
  - Terraces
  - Bunds (graded & contour)
  - Check dams
  - Vegetated outlets & watercourses



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Photos: Singh, 07. 2001

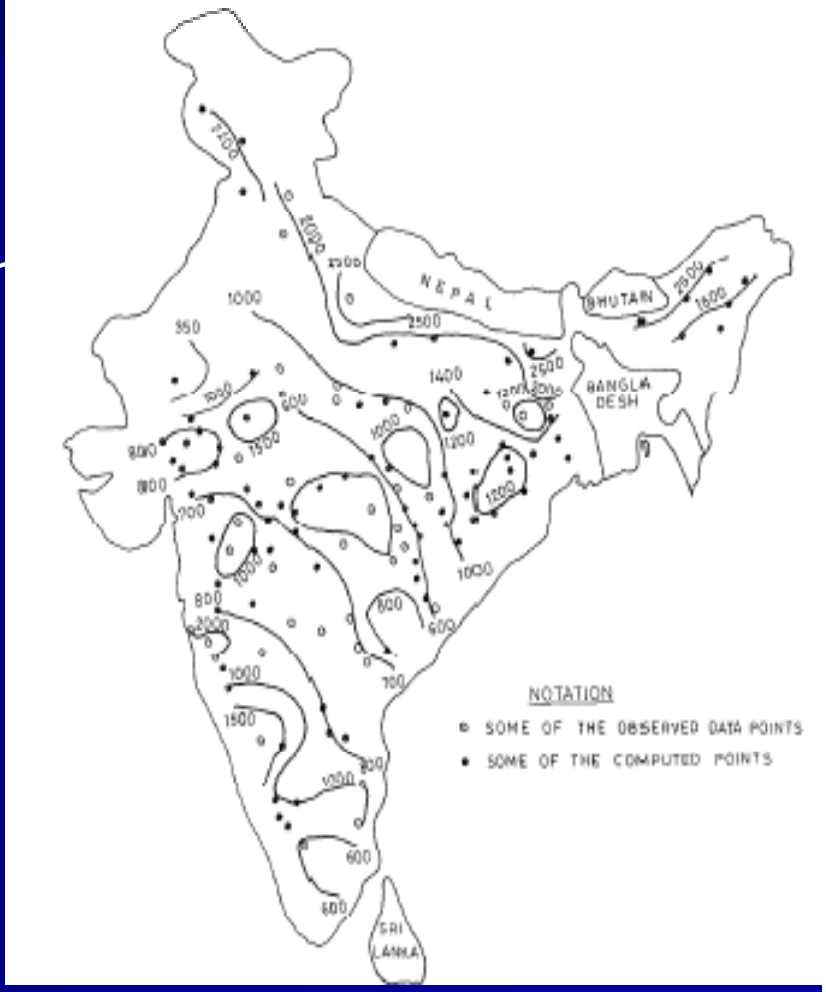
Photo, A.K. Singh, 2002

Case Study: Indian Scenario

- Soil erosion prevalent – almost 55% of total land
- Himalayan & lower Himalayan regions highly affected
- More than 25% reservoir capacity lost

- Erosion rates in India-
- Iso-erosion lines- annual

Erosion rates in ton $km^{-2}year^{-1}$
(Garde & Kothyari, 1987; Kothyari, 1996)



Annual Soil Loss Estimate– Indian Scenario

Region	Land-Use	Soil loss(t/km^2)
North Himalayan forest region	Forest	~280
Punjab-Haryana alluvial plains	Agriculture	~330
Upper-Gangetic-alluvial plains	Agriculture/waste land	~1400-3300
Lower Gangetic alluvial plains	Agriculture	~280-950
North-eastern forest region	Agriculture/shifting cultivation	~2750-4100
Gujarat alluvial plain	Agriculture	~300-3300
Red soil region	Agriculture	~250-350
Black soil region	Agriculture	~2370-11000
Lateritic soil	Agriculture	~4000

Ref: Raj Vir Singh (2000), Watershed Planning and Management, Yash Publishing House

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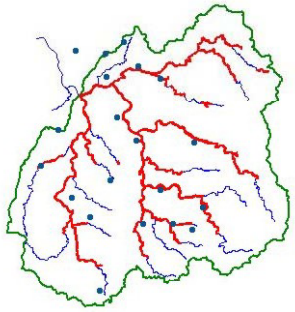
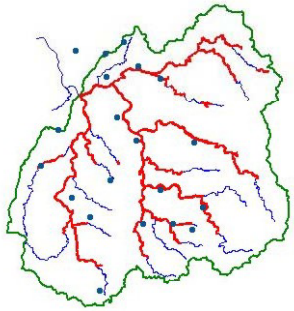


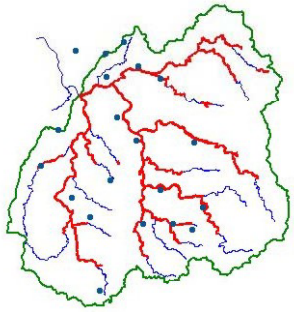
Tutorials - Question!.?.

- **Illustrate the possible soil conservation measures within the perspective of sustainable watershed management practices.**
- Identify the components soil erosion
- Scientific interventions
- Identify the problems
- Identify vegetative & mechanical measures.
- Importance of soil conservation.



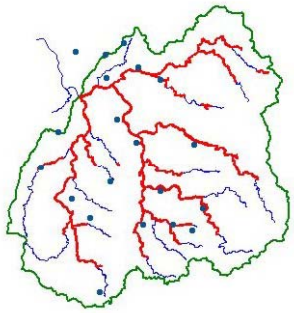
Self Evaluation - Questions!.

- What are the causes and consequences of soil erosion?.
- What is wind erosion & under what conditions does it occur?.
- Enumerate measures adopted for control of soil erosion caused by wind.



Assignment- Questions?.

- Differentiate between geologic & accelerated erosion of soil.
- Illustrate soil erosion processes.
- What are the important factors affecting soil erosion by water?.
- What are different types of water erosion?. Discuss each type.



Unsolved Problem!.

- For your Watershed area, study the soil erosion problems?.
- Identify the problems.
- Find out the ways to control soil erosion problems.
  - Carry out survey
  - Consider traditional practices to control erosion
  - Suggest scientific methods for soil conservation

THANK YOU

Dr. T. I. Eldho
Professor,
Department of Civil Engineering,
Indian Institute of Technology Bombay,
Mumbai, India, 400 076.
Email: eldho@iitb.ac.in
Phone: (022) – 25767339; Fax: 25767302
http://www.civil.iitb.ac.in